SFB 649 Discussion Paper 2011-036

An Indicator for National Systems of Innovation

Methodology and Application to 17 Industrialized Countries

Heike Belitz*
Marius Clemens**
Christian von Hirschhausen***
Jens Schmidt-Ehmcke*
Axel Werwatz***
Petra Zloczysti****

* DIW Berlin, Germany
** Universität Potsdam, Germany
*** Technische Universität Berlin, Germany
**** Freie Universität Berlin, Germany

This research was supported by the Deutsche Forschungsgemeinschaft through the SFB 649 "Economic Risk".

http://sfb649.wiwi.hu-berlin.de
ISSN 1860-5664

SFB 649, Humboldt-Universität zu Berlin
Spandauer Straße 1, D-10178 Berlin

SFB 649 ECONOMIC RISK BERLIN

An Indicator for National Systems of Innovation – Methodology and Application to 17 Industrialized Countries[1]

Heike Belitz (DIW Berlin – German Institute for Economic Research)[†]

Marius Clemens (University of Potsdam & DIW Berlin)[††]

Christian von Hirschhausen (Technische Universität Berlin & DIW Berlin)[†††]

Jens Schmidt-Ehmcke (DIW Berlin – German Institute for Economic Research)[††††]

Axel Werwatz (Technische Universität Berlin & DIW Berlin)[†††††]

Petra Zloczysti (Freie Universität Berlin & DIW Berlin)[††††††]

May 2011

[1] This paper summarizes research of the project “Innovation Indicator“ supported by the Deutsche Telekom Stiftung and the Association of the German Industry (BDI). Axel Werwatz received financial support from the German Science Foundation via CRC 649 "Economic Risk". We thank Astrid Cullmann, Bronwyn Hall, Alexander Kritikos, Adam Lederer, Stephanie Schneider and Tanja Kirn for helpful comments and suggestions and Anne Konrad, Kathleen Ngangoué and Doreen Triebe for research assistance. The usual disclaimer applies.

[†] hbelitz@diw.de

[††] mclem@uni-potsdam.de

[†††] chirschhausen@diw.de

[††††] jschmidtehmcke@diw.de

[†††††] axel.werwatz@tu-berlin.de

[††††††] petra.zloczysti@fu-berlin.de

Abstract

We develop a composite indicator measuring the performance of national innovation systems. The indicator takes into account both “hard” factors that are quantifiable (such as R&D spending, number of patents) and “soft” factors like the assessment of preconditions for innovation by managers. We apply the methodology to a set of 17 industrialized countries on a yearly basis between 2007 and 2009. The indicator combines results from public opinion surveys on the process of change, social capital, trust and science and technology to achieve an assessment of a country’s social climate for innovation. After calculating and ranking the innovation indictor scores for the 17 countries, we group them into three classes: innovation leader, middle group and end section. Using multiple sensitivity analysis approaches, we show that the indicator reacts robustly to different weights within these country groups. While leading countries like Switzerland, the USA and the Nordic countries have an innovation system with high scores and ranks in every sub indicator, the middle group consisting among others of Germany Japan, the UK and France, can be characterized by higher variation within ranks. In the end section, countries like Italy and Spain have bad scores for almost all indicators.

Keywords: National systems of innovation, Composite Indicators, Ranking

JEL Classification: O30, C81, H52

1 Introduction

Efforts to rank performance, in terms of economic growth, quality of education, or investments in infrastructure are ubiquitous. Innovation is another area where countries are being ranked. Well-known examples of ranking countries' innovative capacities include the European Innovation Scoreboard (European Commission, 2009) and the Manager Survey in the Davos Forum (World economic Forum, 2009). Such 'league-tables' are addressed to the public and attempt to determine a country's position among its perceived competitors with respect to the ability to produce new products and services.

There is consensus that an ideal "catch all" variable for innovation is not at hand (Patel and Pavitt, 1995). Thus, innovation rankings are typically based on composite indicators of innovative capacity. Composite indicators summarize the information from various underlying basic indicators and deliver the "bottom line" to the media and the public. Rankings, however, serve another purpose: they are used to pinpoint countries' strengths and weaknesses. This aspect of rankings is particularly important for policymakers and stakeholders, who assess their actions and are being assessed on the basis of such comparisons. To be useful for this purpose, rankings need a rich-enough foundation that facilitates the identification of specific country profiles and differences.

These different aims are serious challenges in the design of rankings. The composite indicator approach immediately raises questions about the selection, standardization and aggregation of fundamental, individual indicators. Moreover, the desire to construct a data base of sufficient width and depth may require data availability that is not easily met thus seriously limiting the set of countries that can be compared.

In this paper, a composite indicator of innovative capacity that addresses these challenges is presented. It is based on a broad set of basic innovation measures that are ultimately aggregated into a single composite indicator from which overall country rankings are derived. It is designed to stimulate a well-informed policy debate, and thus to have –at least relative to other rankings- considerable width and depth. This is also called for by the focus on 17 highly developed countries from Europe, North America and Asia.[2] These countries are, in many ways, similar as they all have the important scientific, political and economic institutions for innovation already in place.

To identify their differences it is necessary to go beyond a set of standard indicators. We thus draw upon a variety of data sources and topics, including "soft" factors such as the attitudes of the population towards innovation and technical progress. The resulting data base includes more than 180 variables that are grouped by topic and are aggregated in several stages.[3] Aggregation culminates into

[2] Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Great Britain (UK), Ireland (IRL), Italy (ITA), the Netherlands (NLD), Spain (ESP), Sweden (SWE), and Switzerland (CHE), represent Europe. North America consists of the United States (USA) and Canada (CAN), while Asia comprises of Japan (JPN) and South Korea (KOR).

[3] The maximum number of included single indicators differs from year to year. Consequently, the indicator is more flexible to consider new aspects and theories and can be interpreted as an innovation process itself.

an overall composite indicator of innovative capacity. It rests on two pillars: one representing the national innovation system, the other representing the societal climate for innovation in a country.

The system side consists of seven domains: education, research and development, regulation and competition, financing, demand, networking, and implementation in production – each represented by its own composite indicator. The climate side is based on three domains, namely: Innovation culture, attitudes towards science and technology, as well as social capital and trust. Principal component analysis is used to determine the weights of sub-indicators in the aggregation process. In the final aggregation steps, we rely on expert assessments of the importance of the different domains.

Based on data from 2004 to 2008, we find two groups of countries regularly appearing at the top level: “small” Scandinavian countries (Sweden, Finland, and Denmark), Switzerland and the U.S. At the bottom of the list, Spain and Italy are regularly far behind the rest of the field.

The applied methodology further allows clustering groups of countries based on intermediate composite indicators (Schneider, 2008). Results suggest that an “easy” transfer from midfield into the leading group requires much more than just turning a few dials in the innovation policy set. In-depth analysis of individual countries’ profiles can be conducted in accordance with the ranking’s original purpose. Taking Germany as an example, we illustrate how a detailed strength and weaknesses profile can be derived.

The paper is structured in the following way: Section 2 summarizes the conceptual approach; Section 3 discusses the composition of the national innovation system, followed by a description of the underlying data. Section 4 introduces our notion of innovation climate, while Section 5 presents the methodology used and principles of aggregation. Section 6 provides the main results of the indicator, in detail for 2008. It is supplemented by a sensitivity analysis of the aggregated indicator with respect to changes in weights and the composition of sub-indicators in Section 7. Section 8 concludes.

2 Concept and Construction

In neoclassical growth models with endogenous technological advantage, innovation is explained as a result of reciprocity between human capital accumulation, R&D and firms production.[4] The knowledge transfer that combines all three components is in most instances assumed to be a public good. Hence, the government has to procure basic knowledge and should interfere if spill over effects appear. Aghion and Howitt’s (1992) extended model combines the endogenous growth approach with the Schumpeterian theory of “creative destruction” that focuses on firms as an innovative actor. But even with the inclusion of private incentives for financing and investing in education or R&D, the framework of neoclassical models remains restrictive.

Nelson (1997) suggests that many independent variables and causal relationships are blanked out by general theory. Furthermore, others (Ames and Rosenberg, 1963, Nelson and Winter, 1982,

[4] e.g. Romer (1990), Barro (1997), Czernomoriez (2009).

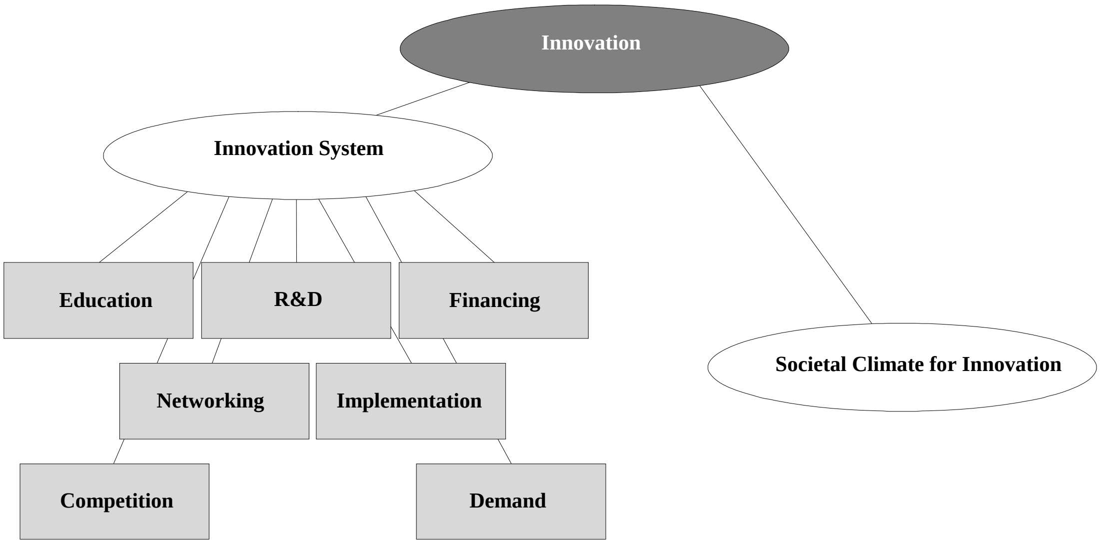
Nelson and Wright, 1992) emphasize that technological innovations cannot freely circulate between actors and country borders, because their development and utilization may be bound to firms, networks and other institutions. From that perspective, innovation is rather determined by the "interplay" of different actors than by technological levels or developments. This innovation network approach combines purely economic factors (supply push and demand pull factors) with social structures that support innovative actions and reactions within an interdependent system (Callon, 1986, 1991). At the risk of breeding market failure through the incentives for unintentional agreements and thus for distortions of competition, the government has to set rules and norms, the effect of which is quite ambiguous. Hence, innovation always has a country-specific component that may explain differences in competitiveness, growth and other economic-related questions (Porter, 1998).

Innovation is a creative and interactive process that goes far beyond education or R&D, and it occurs within a system of norms, institutional regulations and organizations. Freeman (1987, p. 1) defines these "national innovation systems" as "networks of institutions in the public and private sector whose activities and interactions initiate and diffuse new technologies". The literature can be separated into two different approaches: Nelson (1993) detects innovation systems with descriptive methods based on case studies. Lundvall (1992) captures the innovation system in a more theoretical setting. Both approaches share the characterization of national innovation systems by determinants of innovation processes. They diverge in substance by identifying the main element of an innovation system as either distinguished by actors or interaction. Starting with the general task to construct an indicator that is able to measure the complexity of the innovation system, we define the components that explain the innovation system.

The national innovation system takes centre stage in our indicator concept. The central actor of that system is supposed to be the private sector. The framework for innovative firms within the national innovation system is assigned to the following seven subsectors: Education, research and development, financing, competition and regulation, networking, implementation (on world markets) and demand. But national innovation systems are also influenced by historic factors such as common societal attitudes and citizen values.[5] Thus, an integrated approach should consider the "societal innovation climate", which can aid innovations if, for example, the citizens of a country are open-minded about new technologies or innovations. Furthermore, there are hidden risks in the effort to develop new technologies and products. In order to be innovative, a society must have the courage to change, trust in the actors who bring about innovation, and hold a fundamentally positive - but not necessarily uncritical - view of science and technology. For this reason, we evaluate public opinion surveys on the process of change, social capital, trust, and science and technology. Figure 1 displays our general framework for measuring innovation.

[5] Some studies investigate the relation between historical, societal and cultural variables on economic growth. See i.e. Granato et al. (1996), Barro and McCleary (2003), Frey and Stutzer (2002), Florida (2002) and Butler et al. (2009).

Figure 1: National innovation system



Source: Werwatz et al. 2008

The next step is to identify indicators explaining the different sub components. Our approach is to select single indicators not only cover direct output and input variables such as R&D expenditures and patents, but also factors affecting the entire innovation process, e.g. education and regulation. Finally, an empirical method is chosen to aggregate the different sub components into a composite indicator. Hence, empirically the indicator follows a bottom-up approach. This allows us to use a very rich database enabling detailed analyses of the bottlenecks in national innovation systems.

3 Composition of the national innovation system

The term “national innovation system” refers to the enterprises, institutions, and surrounding conditions that influence the process through which innovations arise. The system ensures that highly qualified individuals (education), new knowledge (R&D), and sufficient capital (financing) come together in the process of innovation and that key players in innovation – particularly companies – are responsive to impulses from partners (networking), other competitors (regulation and competition) and national and international customers (demand) and implement new products, services, and organizational solutions (production and implementation). These seven areas, as described below, are underpinned by a number of sub indicators, which, taken together, provide a measure of the strength of the national innovation system.

Education

The innovation capacity of a country is significantly influenced by educational levels.[6] The knowledge imparted by schools and universities is an essential input factor for the development of new processes and products (Becker, 1964, Baumol, 2004). Thus, an innovation-friendly education system must seek to create highly educated and creative thinking personnel. The sub indicator education consists of four main elements: The *costs and expenditures* of financing the educational system by different sources per attendant measure to what extend countries spend their resources for education and training. *The quantity of school and university attendance* – especially in natural scientific and technical studies – is a common used indicator to account for the educational impact on innovation. Additionally, the accesses of male and female, domestic and foreign students to post graduate degree programmes are implemented as proxies for future scientists or engineers. *Qualitative measurements*, such as PISA scores, act as an early indicator for prospective quality of human capital. In addition, university rankings provide evidence for quality and potential of domestic universities.[7] Firms and institutions have to prepare their employees for new challenges with on–job-training. Therefore, the corresponding indicator uses a combination of OECD and WEF data to measure the *participation in lifelong learning*.

Hence, the education indicator depicts qualitative and quantitative aspects of human capital. Education and Training are regarded as the most important investments into human capital, which is consists of aggregated knowledge, skills, behavioural attitudes and creativity.[8] Thus, it is intrinsically tied to personality and an indispensable factor for innovation.

R&D

Research and Development are the central prerequisites for innovation and invention. Based on common approaches, the R&D indicator is separated into two causal relations. Public and private R&D is only possible if enough scientists and specialists are available. The share of scientists out of the total population gives information about the importance of R&D in a country. Accessory, the public and private expenditures of institutions and firms, accounts for the value of *R&D input*. The *R&D Output* is highly influenced by the number of patents. Although they do not cover all innovative products and ideas, Patents are considered to be good indicator for R&D output (Smith, 2005). In conjunction, inputs and outputs can be interpreted as defining the knowledge production frontier.[9] Basic research is not generally application-oriented, but it provides the foundation for applied research. Thus, it is covered by scientific citations and publications in renowned journals. An additional component measures the output quality surveyed by the WEF by means of subjective assessments of managers.

---

[6] The OECD classified educational levels into primary, secondary, tertiary and different interstages. See. Education at the Glance (2009)

[7] Hanushek and Wößmann (2007) analyze the quality as the key issue of educational policy.

[8] The indicator does not comply for total human capital as it is also determined by health care spending and cultural and social aspects. See Mulligan and Sala-i-Martin (2004)

[9] Cullmann et al. (2011) measure R&D efficiency using these variables.

Financing

The time between the ideas and the market success of an innovative product is characterized by a high degree of uncertainty. Often risky innovations do not even cover the costs of R&D. A financial system needs to support innovative entrepreneurs in early stages of their start-up process with different forms of financing. Furthermore, established innovative firms should have an efficient access to equity and credit markets. The financing indicator is divided into the following sub components: *General financing conditions* contain the goodness of national banking, equity, credit, venture capital, and asset markets. The second part concentrates on the *financing situation for high-technology start-up companies*. In particular the share of different stage venture capital and informal investors of GDP and population are indicators for the ease of capital access. These variables are partly derived by qualitative WEF measurements. Finally, government aid drives, in multiple cases, the development of next generation technologies. The extent of subsidies, *public financed R&D expenditures,* in companies and governments' *tax policy* are implemented in the third part.

Demand

The process of technology diffusion is closely related to learning, imitation and the interaction of developers and users (Hall, 2005). An innovation process is completed with the introduction and diffusion of the product on the market. Thus, the demand pull factor – initialized by consumer and users – stimulates the innovative activity of companies. Lundvall (1988), Fagerberg, (1995) and Porter (2004) show that collective learning processes between producers and technology interested users and the overall demand conditions are pivotal determinants for the competitiveness and innovation capacity of firms. Additionally, the concept of lead markets underlines the active role of an innovative consumer whose demand spreads products from domestic to world markets (Beise, 2001). The demand indicator consists of the *gross domestic product per population* and the *domestic demand for innovative products.* The *demand quality* is rated by the evaluation of companies in matters of buyer's sophistication, firm level technology absorption and government procurement of advanced technology products.

Implementation

An innovation process reaches its target if companies are able to produce and supply new products and services to the market. We focus on the production and sales of R&D-intensive products and services as well as the R&D trade balance. The emphasis on R&D intensive and knowledge intensive industries is a comparative advantage essential for high-wage countries (EFI, 2009). Thus, *research-intensive value added, labour force* and *balance of payments per population* in these industries provide evidence on market success.[10] Of special interest are cutting edge technologies and fast growing start-ups due to their significant impact on economic growth (Wong et al., 2005). The

[10] We use NIW/ISI Frauenhofer lists (Legler and Frietsch, 2007) to identify the sector classification of R&D and knowledge intensive sectors.

implementation of innovation activity must be supported by *general and R&D-specific infrastructure*. Valuations of the *Transport and Energy systems, Network Readiness* and *E-Readiness* are introduced to gauge the general infrastructure, the ability and willingness to use information and communication technologies.

Regulation and competition

Innovator's lives are made more difficult through inflexible recruiting regulations, lengthy approval processes for start-ups and new products, extensive liability rules. However, regulation is not always synonymous with "bureaucracy" or "Paper Mountains" when it comes to innovation. It can foster the process of innovation and shape market developments in a particular direction. The Product Market Regulation (*PMR) index* of the OECD is used to incorporate the regulation of product markets and professional services (Conway and Nicoletti, 2009). The extent of *competition, fighting corruption* and the *competition intensity* are linked together as measurements for competition.

Networking

Good teamwork pays off – especially in the innovation process. This is because a whole range of skills and knowledge is required to develop and implement sophisticated new products. Companies that work with others, exploit external research resources, and liaise closely with higher education establishments often have significant advantages over competitors. The "networking" indicator rates the extent and quality of collaboration at various locations of innovation. A number of factors are taken into account: The *degree of inter-company networking* and *alliances with suppliers and customers* are supposed to have a positive effect on innovation activity as long as competition is prevails. *Cooperation and knowledge transfers* result from an increasing division of labour between research institutes and industries. *Global knowledge networks* and the concept of *clusters* highlight the advantages of cooperation in geographical closed-by companies, sectors and institutes (Porter, 1998).

4 Composition of the national innovation climate

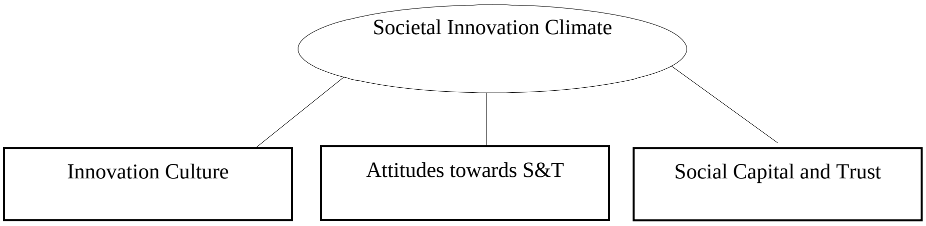
An additional component for analysing and comparing national innovation systems is the consideration of "societal innovation climate". Although many studies find that societal attitudes and moral concepts - which are formed though history, culture and social life - have a significant effect on innovation and growth, these are not mentioned in other studies comparing national innovation systems.[11] The main idea behind the construction of an innovation climate indicator is that countries differ in the willingness of their residents to encourage and adopt innovations (Belitz and Kirn, 2008, Gee and Miles, 2009). An open-minded and tolerant societal climate is a cultural medium where innovative talent and creativity can develop and grow rapidly. In contrast, in societies with narrow limits based upon tradition, norms and ideologies, the innovation process is hindered. New scientific

[11] i.e. European Innovation Scoreboard (2009), STI Indicators (2009).

developments and technological applications require societal adjustment of the regulatory framework for research and utilization.[12] Thereby open societies with a general interest in innovation combined with a systemic trust in scientific, political, and economic institutions more willingly accept new technologies.

Figure 2 summarizes the societal climate indicator that combines the three components ”Innovation Culture”, “Social Capital and Systemic Trust”, “Attitudes towards Science and Technology”.

Figure 2: Societal climate for innovation



Source: own illustration

Innovation Culture

“Innovation culture” is mainly ascribed to Inlgehart (1990, 1997), who finds that industrialization, cultural change and post industrialism lead to a rational understanding of science and an increasing importance of the production factors human and social capital. Thus, societies with authority-based conformance hinder innovative and entrepreneurial activity. In contrast, creativity and innovations are fostered by a societal value structure where rational secularity outweighs traditional religious authorities and where individual self-fulfilment is supported by openness and tolerance.[13] Florida (2002a, 200b) shows that the innovative capacity in US-American regions is greater if society is open-minded and tolerant because creative and well-educated people want to live in such communities.[14] Further studies by Frey and Stutzer (2002, 2006), Barro and McCleary (2003) and Inglehart, (2004) emphasize the effects of happiness and well-being as well as religion and cultural values on innovation and economic growth.

Besides open-minded and rationality orientated citizens, an innovative society needs an optimistic and confident attitude towards entrepreneurial risk. The innovation process is uncertain and decisions are made on the basis of incomplete and asymmetric information. Therefore, entrepreneurs should have an “entrepreneurial spirit” that can be divided into visionary beliefs and leadership abilities (Schumpeter, 1934).

[12] The implementation of gene technology initiated a widely discussion about the ethical constraints and their utility for men through its medical research and usage. Similar controversies within and between national cultures exist i.e. in nuclear power, energy use.
[13] e.g. Inglehart and Welzel (2005)
[14] The „brain gain” effects for open and tolerant societies are also discussed in Czernomoriez (2009).

Furthermore, in many industrial countries the role of women in knowledge-based processes is weak in comparison to men. Traditional societal norms and moral concepts prevent the integration of women (Valian, 1999, Tenenbaum and Leaper, 2003). However, the predicted demographical problems in industrial countries, paired with an increasing service and knowledge-based economy structure, make the integration of women into knowledge-intensive production a key element for ensuring technological competitiveness. In summary, general moral concepts of openness and tolerance, the attitude towards entrepreneurial risks and the participation of women in innovation are incorporated into country's "Innovation Culture".

Social Capital and Systemic Trust

The public discussions and evaluation of innovative technologies is marked by an *ex-ante* asymmetric information structure. This trust-dependent situation can be explained with the Principal-Agent-Theory (Arrow, 1972). Agents who develop a new technology are dependent on the acceptance of society. Thus, they try to inform the public through reports, mass media and other channels; but the public accepts the innovation only if they trust the principal. If both actors have a low interrelated trust or distrust, there are high control and transaction costs (Clague, 1993).[15] While the PA-Theory analyses two representative actors, a national innovation system is full of network relations, civil engagement and cooperation all depending on systemic trust. The concept of social capital incorporates this network structure, by considering the social relationships between citizens and institutions. Hence, social capital with systemic trust in institutions, as well as the willingness and ability to work and live together, are prerequisites for economic growth and innovation.[16]

Putnam (2003) explains that social capital is built through the voluntary participation and engagement in clubs and organizations. Welzel et al. (2006) broaden this approach by introducing non-institutional social capital, such as attending lawful demonstrations, joining in boycotts or signing petitions, because these "elite-challenging actions" reflect an efficient social network.

While social networks indicate interpersonal trust relationships, they are not automatically equivalent with a systemic trust relation, although both kinds of trusts are interrelated.[17] The trust in a national innovation system is linked with the confidence in its main actors, institutions, scientists, mass media, politics, and firms. If the systemic trust in the institutions of a national innovation system is large, the willingness of the society to cooperate, compromise and accept innovations is high, while monitoring and transaction costs are small (Akcomak and ter Weel, 2009). In summary, the "Social Capital and Systemic Trust" indicator accounts for these influences on the national innovation system.

Attitudes towards Science and Technology

---

[15] Clague (1993). Luhmann (2000) found that trust and distrust are functional equivalents. Both can increase rapidly if a threshold level is reached, but they can also rebuild slowly if the actual trust level is beyond it.
[16] e.g. Jacobs (1961), Fukuyama (1995), Weizel et al. (2006)
[17] e.g. Rippberger (1995), De La Motte et al. (2010)

A general interest on science and technology paired with positive attitudes has effects on the preferences for innovative products, the acceptance of new production processes and the attendance at educational institutions. The expectations and perspectives on future social gains of product and process innovation is an additional component that affects societal preferences. Finally, countries differ in their opinion if publicity or experts should control and regulate the research and application of new technologies. Gaskell, et al. (2005) distinguish this more generally by asking if the decision about new technology should be geared to scientific knowledge or moral and ethical concepts. They show that who citizens prefer decisions by experts and on the basis of scientific criteria are more optimistic about new technologies. The interest of citizens, their perspectives about future utility and the belief of government regulation are the main components of the “Attitudes towards Science and Technology” indicator.

5 Data and Methodology

Data

The innovation system indicator is based on “hard” and “soft” indicators. The latter are mostly represented using World Economic Forum (WEF) Manager Survey Data. The WEF Survey is carried out every year and investigates the sentiments of 100 top managers of every participating country. The “hard” indicators stem from a variety of OECD datasets (EAG, MSTI, PISA, STAN, STI) and are completed by data from other sources (Transparency International, USPTO, EPI, EUROSTAT, EUKLEMS, GEM, NSB, Thomson ISI) as well as other composite indicators (NRI, EIU, OECD B_Index). The implementation of “hard” and “soft” facts satisfies the claim for considering quantitative and qualitative aspects (Freudenberg, 2003).

The “societal climate” can only be measured using public survey data. There are two common sources that compare attitudes of societies in an international context. While World Value Survey Data were used to consider openness to new technologies and formation of social capital, Eurobarometer Data incorporates people´s trust and concerns about science and technology.

Countries’ size, population, exchange rate or price specific effects are eliminated by considering per capita values and purchasing power parities. Latest data available is used for all variables. Therefore, a composite indicator for a specific year is not a snapshot rather than a filmlet and dynamic interpretations of changes between periods should be treated with caution.

Methodology

All variables are standardized, since they were not only collected from different sources but were endowed with varying scales, units and ranges.[18] Single variables are scaled on a same basis. The OECD (2008) recommends different techniques depending on the final objective. The innovation indicator is based on a “Distance from the best and worst performer” approach, which lengthens the

[18] Additionally, the PCA methodology requires standardized variables.

range between similar variables. This standardization is used because the comparison of a very similar group of countries – high income OECD industrial countries with few outliers – asks for a method that gives greater weight to variations (OECD, 2008). Additionally, deviation between the top and bottom are rescaled to a range of 1 to 7, since many of the individual indicators from the global manager survey (WEF) already use this scale in their “raw form”. The following transformation rule is applied:

$$X_i = 6 * \frac{(Y_i - Y_{\min})}{(Y_{\max} - Y_{\min})} + 1$$

The original values of individual indicators *Y* for country *i* are assumed to influence the innovation process positively, thus, a higher value is better than a lower one. The standardization method is carried out at every single stage of aggregation.

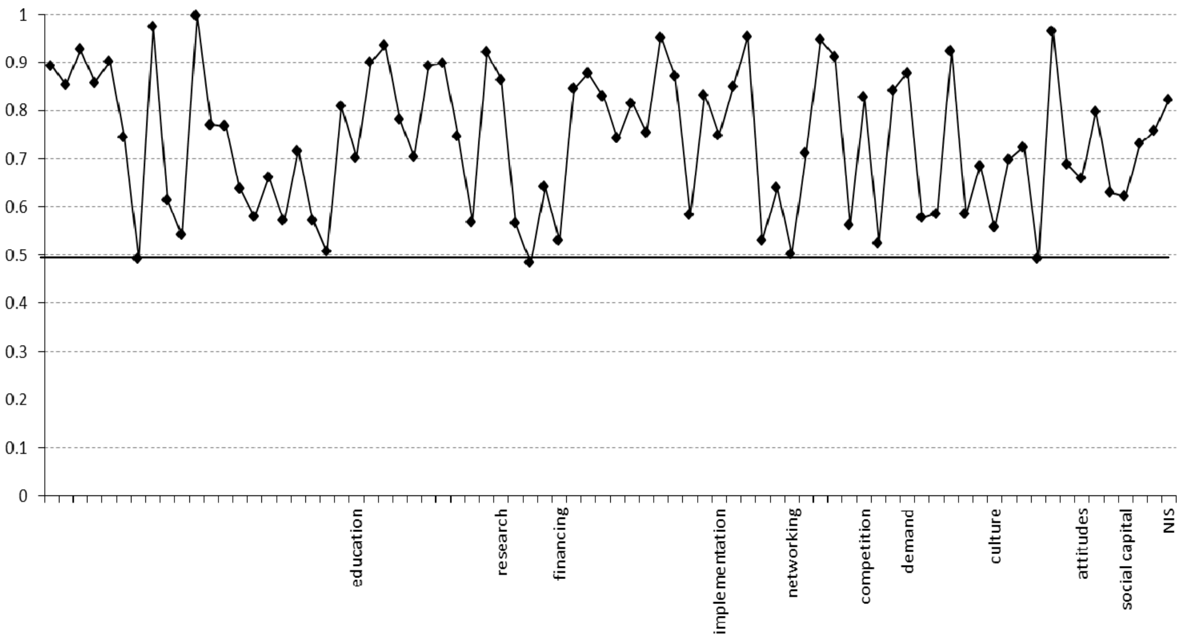
In line with rewarding indicators with higher variability between similar industrial countries we use the Principal Component Analysis (PCA). We use PCA and its first component merely as the method for measuring the weights. If some of the original (single) indicators, denoted by Z_1, $Z_2 \ldots Z_j$, are highly correlated, at least one variable contains similar information. Thus, it can be omitted without any loss of information given by variances and correlations or covariance.

Beginning with the single indicators we have up to eight stages of integrating and combining single and sub components into the aggregated indicator. In all aggregation stages, except the final two, PCA is applied. The explanatory power is measured by the dispersion (variance and covariance) of the first component relative to the total variation of all components.[19]

Figure 3 shows the share of the variance explained by the first component of all sub indicators. The single aggregated components underlying one of the seven sub indicators are labelled. In the majority of cases the shares are higher than 50% (two exceptions) and often higher than 60%. The shares for the NIS and social climate component together with the total indicator are located at the right outside margin of the figure. Both components explain more than 70% of the total variation.

[19] The covariance matrix is assumed to be a positive definite matrix which ensures that all eigenvalues are strictly positive. Since we define the contents of first component before calculating the weights, the original variables are not positively correlated in some rare cases. Under these specific circumstances the composite indicator is computed by using the relative variances of single variables instead of combining it with covariance.

Figure 3: Share of variance explained by the first principal component



Source: own calculation

The weights in the second to last stage, in which seven sub-indicators of systemic strength are aggregated, are based on expert judgments having participated in a written survey conducted by the German Institute for Economic Research Berlin (DIW) and the Association of the German Industry (BDI) in 2005 and 2006. In the final stage, the system indicator is weighted 7/8 when integrated with the “societal climate” indicator to produce the overall innovation ranking.

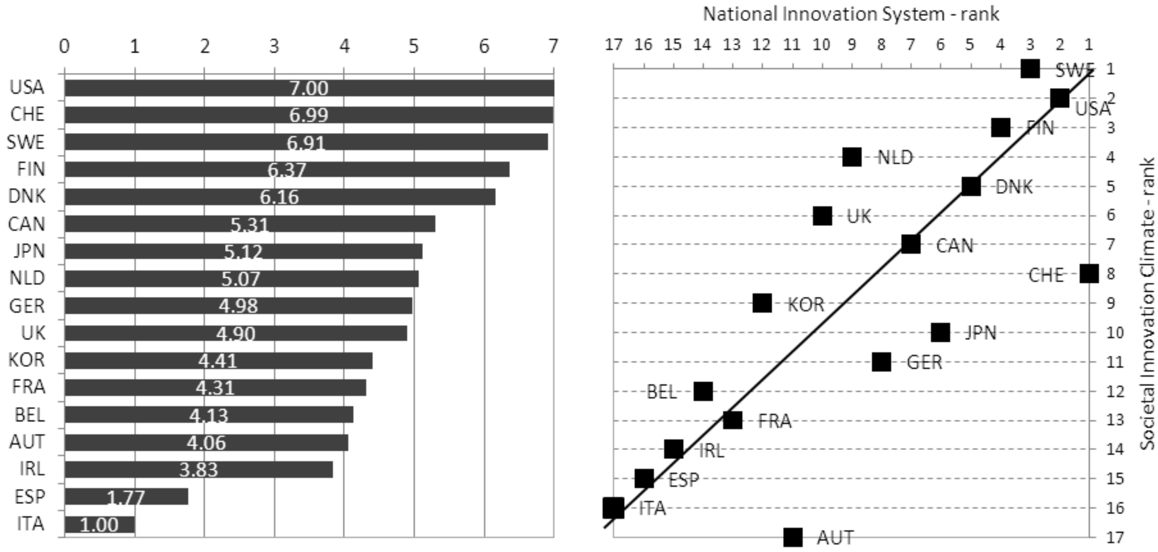
6 Results: the German innovation system in international comparison

Innovation System and Profile

The overall indicator can be analysed on the basis of two objectives: The first principal component can be interpreted as a performance measure. It shows which country has the most competitive national innovation system among the countries included. Using the method and weights explained above, the overall ranking of the seventeen countries in the 2009 innovation system indicator is led by the United States (Figure 4). The US is followed by Switzerland, Sweden, Finland, and Denmark. There is little variation within this leading group: USA, Sweden and Switzerland are very close together at the top of the innovation ranking. Finland and Denmark are behind the top trio but differences with the lower ranks are wider.

The leading group is trailed by a broad middle range, extending from 6th (Canada) to 15th place (Ireland). Canada, Japan, Netherlands, Germany and the UK form the upper-middle range. Korea, France, Belgium, Austria and Ireland lag behind within a lower-middle range. Spain and Italy land at the bottom of the list.

Figure 3: National innovation system and innovation climate – results 2009



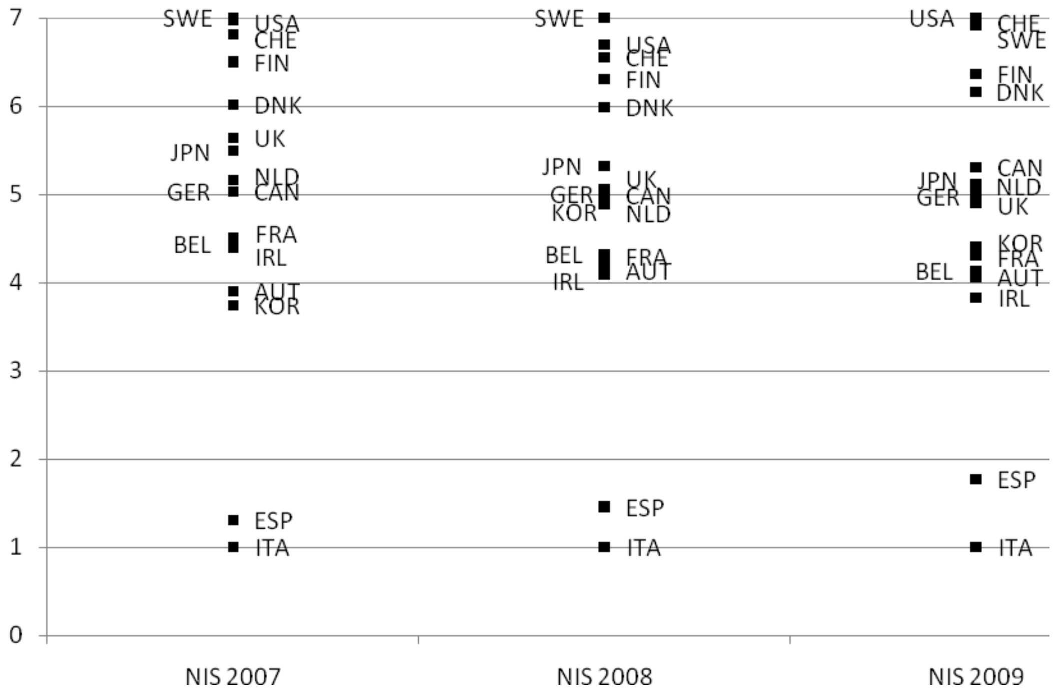
Source: own calculation

The right hand panel compares the differences in ranks between the national innovation system and the climate component. [20] All dots to the left of the 45°-line represent countries that have a better overall rank by considering the innovation climate. If the national innovation system is examined without its societal climate, Switzerland ranks at first place followed by the same leading group consisting of the US and the Scandinavian countries. All German-speaking countries and Japan lose between 3-8 positions if innovation culture, values and beliefs are included.[21]

Another way to gain insights into the determinants of national innovation systems is to analyse short-term dynamics. In 2007, Denmark, UK and Japan were on the verge of accompanying the USA, Switzerland, Sweden and Finland (Figure 5).[22] While Denmark caught up in 2008 and tightened its rank in 2009, Japan and the UK fell back into the middle group. The top position changes within the leading group should not be overstated, since the trio of the USA, Sweden and Switzerland are close together every year.

[20] The correlation between innovation climate and the system component is 62-80%, depending if someone uses Rank, average or weighted average values.
[21] Detailed Results are provided in Table A.1 and Table A.2.
[22] The rankings for the time period 2007-2009 computed with the same variables and method. A change in position for single countries is not inevitably attended by an improvement of the national innovation system. It could rather depend on a worsening of any other country.

Figure 4: National innovation system- results 2007-2009



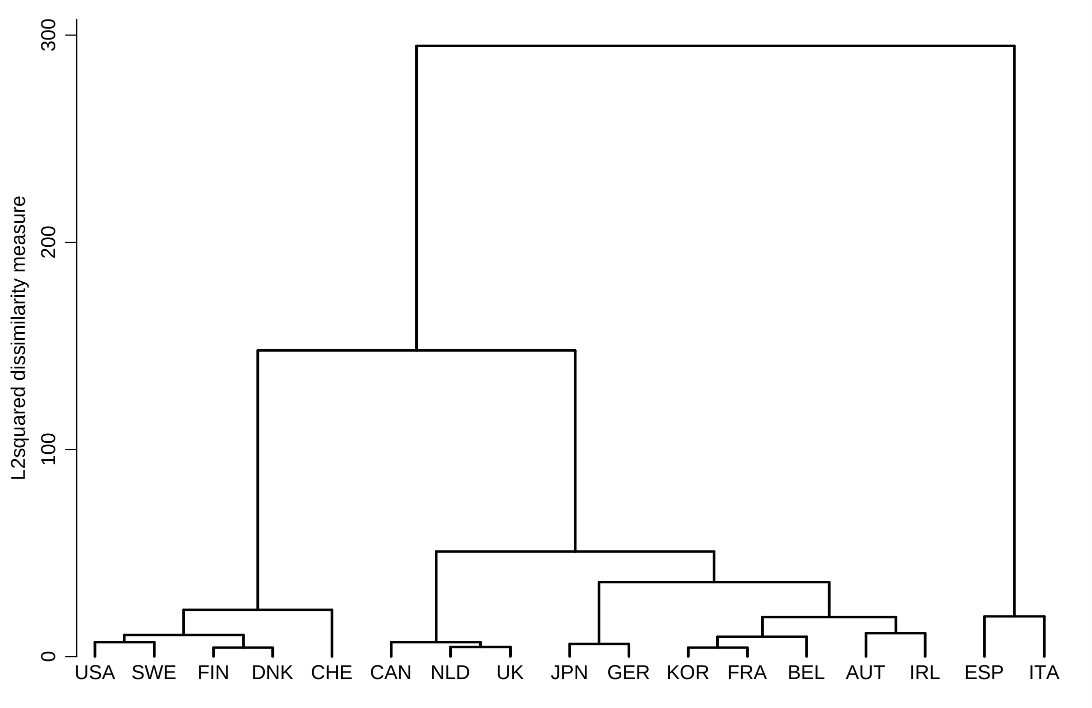
Source: own calculation

Countries can be separated into innovation leaders, followers and lagging groups. The evidence for three different groups of innovation system levels is identified using cluster analysis on the basis of a Wards-Linkage-method. The analysis is conducted with (Figure 6) and without innovation climate (Figure A.1). If the corresponding dendrogram is derived without the sub indicator "innovation climate", the groups correspond to the performance ranking (Werwatz et al., 2008, Schneider, 2008).[23] While innovation leaders have high scores for almost all sub indicators, the countries in the middle group have a higher variation between the sub components. Thus, the performance of countries innovation capacity is strongly related to an innovation system rather than to individual components. A country in the middle group seems only be able to reach the leaders if it addresses its weaknesses while strengthening the rest. The country groups change if we introduce the innovation climate components. The cluster analysis then tends to merge countries on the basis of language and geographical proximity. The first cluster not only consists of the US and the Scandinavian countries but is completed by Switzerland. It is characterized by relative low variation between sub components, independent of overall rankings. Additionally, the countries have close language and geographical ties. The second group includes Asian countries (Japan, Korea), Central Europe (Austria, Belgium, Germany, France and Ireland, the Netherlands) and Canada. Their innovation profiles have a high variation between the sub indicators. As previously described, the

[23] The cluster analysis was made for the innovation indicator 2007 and 2008. We use the same methods for grouping countries in this study and found quite similar results.

German-speaking countries and Japan have weaknesses with respect to innovation climate, financing and strengths in implementation, demand and networking. Spain and Italy establish the third group.

Figure 6: NIS – Dendrogram (WL Method)



Source: own calculation

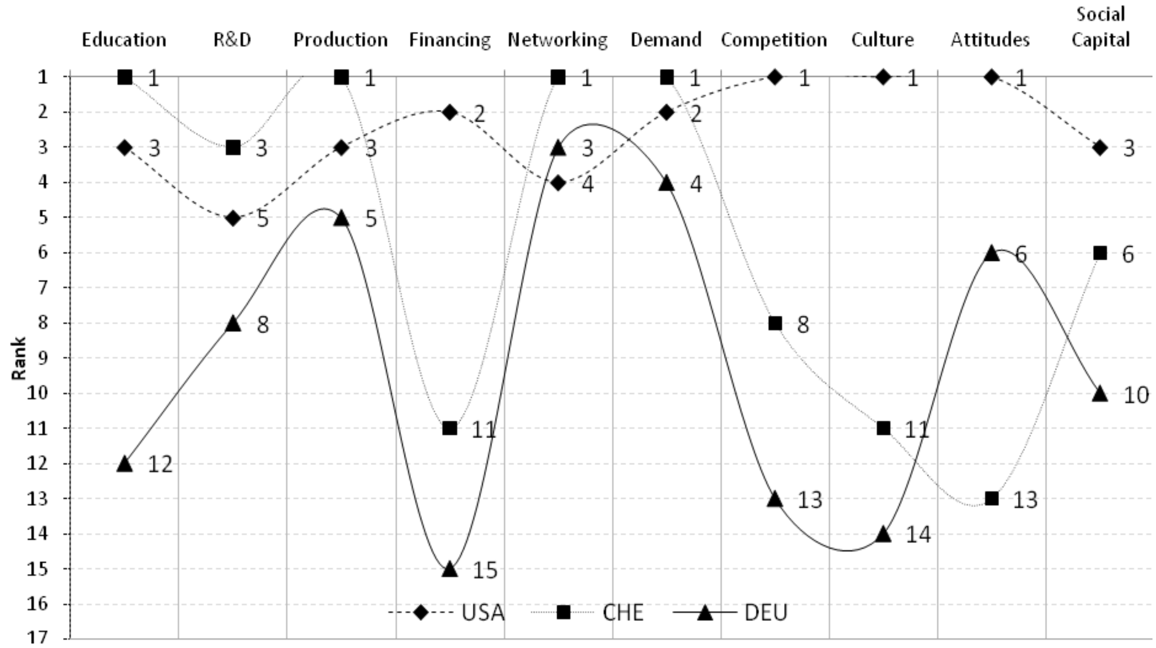
Starting from these first insights, we now concentrate our analysis on three countries: the USA, Switzerland and Germany. We chose these countries because of (1) the top positions (USA, Switzerland); (2) their differences in performance and profile within and between groups; and (3) the high country-specific variation in system and climate scores (Switzerland, Germany) (Figure 7).[24]

The first conclusion to be drawn is that Germany does not truly stand out in any particular area. The overall impression of an average position thus largely carries over to the separate components of the innovation system. Germany has strong advantages in the category of networking (3rd place) and innovation-friendly market demand (4th place). Germany also fared well in the overall ranking in the category of production and market implementation of innovations (5th place). These "systemic strengths" are supported by particularly good scores in two areas: the market success of R&D-intensive industries, and networking of companies. The research facilities and the research system together with the general attitudes towards Science and Technology reach mean scores (8th and 6th place). Yet marked weaknesses are also in evidence, despite these strengths. Internationally compared, the innovation financing (15th place) is rated as poorest indicator. Germany is also relatively weak in the areas of innovation culture (14th place), "competition and regulation" (13th place), educational system (12th place) and social capital (10th place).

---

[24] Results for the sub-indicators (rankings and scores) of all countries are provided separately in Table A.3-A.9.

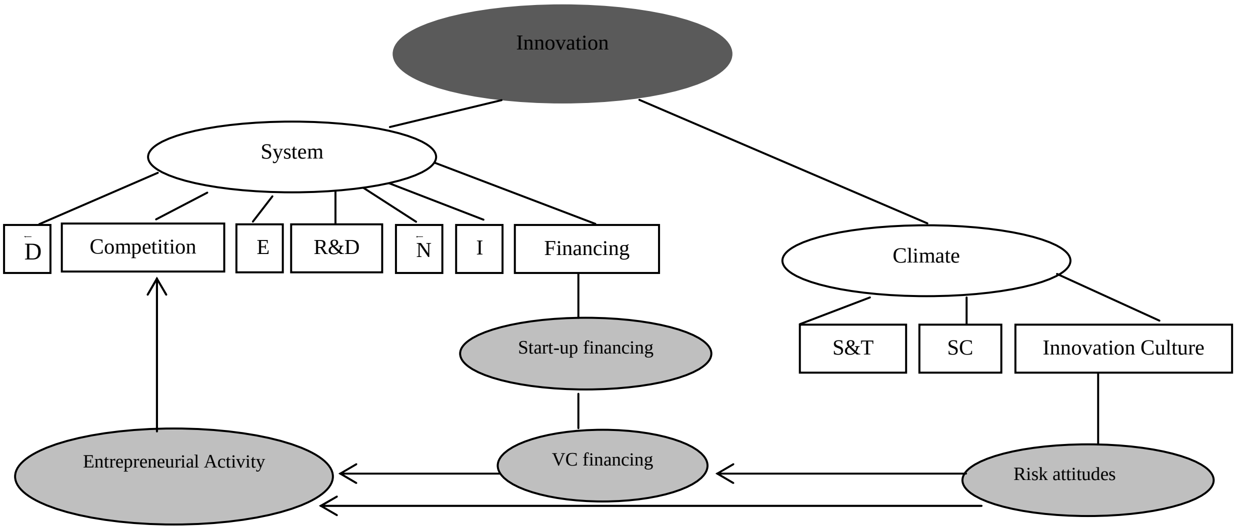
Figure 7: Innovation profile of the USA, Switzerland and Germany



Source: own calculation

Innovation financing remains a grave weakness of the German innovation system. Only Japan and Italy offer worse terms of financing for innovative companies. In light of these results, the following fact gains extra significance: the internationally available data used to compute this sub-indicator was not yet affected by the financial crisis. Even before the economic downturn, the German innovation system was hampered by insufficient innovation financing. The hierarchical structure allows for a top to bottom analysis in order to detect the bottlenecks within problem zones (Figure 8). The sub indicators “general financing conditions” and the “government financing” are better than the overall financing indicator rank, but the start-up financing conditions are worse (15^{th}). By scanning lower financing layers gradually two factors were found that account for the weakness in innovation financing. At first, there exists a lack of venture capital for the risky undertaking of starting a new high-tech company. Additionally, possibilities to access credit and capital markets are not available alternatives for high-tech entrepreneurs. The financing options that entrepreneurs value as positive are government funding and informal investors. The founding of new companies is particularly important for the process of innovation in high-tech sectors. In Germany, however, there is a lack of capital access for the risky undertaking of starting a new high-tech company, which acts as market entry barrier. Established companies thus face less pressure from new competitors. Thus, low entrepreneurial activity discourages greater competition in high-technology industries. However, we find evidence for this transmission channel by analysing the sub indicator “competition and regulation”: Germany’s competition intensity is at the top, while its corruption indicators are in the middle group of all countries. But entrepreneurial activity is very low (13^{th}), especially the opportunity formation. The “innovation culture” is also linked with the financing indicator by the risk attitudes. Germany´s bad position in “innovation culture” can be traced back to a lack of readiness to assume an entrepreneurial risk (17th place). In summary, a high risk aversion combined with small venture capital access and little financing alternatives are reasons for the weak situation in innovation financing and competition.

Figure 8: Analysing Germany's weakness in financing and competition



Source: own illustration

Another German weakness lies in the area of education. The educational system is not well funded, compared to other countries. Germany is in 12th place. According to government targets, expenditure on education should rise to seven per cent of GDP in 2015. Prior to these goals, in 2006 Germany only invested 4.8 per cent of its GDP in education, well below the OECD average of 5.5 per cent. It ranks below-average in quality measures (13th place) such as international university rankings and other quality comparisons e.g. the PISA study. Germany produces relatively few graduates with tertiary degrees (11th place), and also fares poorly in the area of further training (13th place) By analysing the different layers, we detect that the main problems is in the low share of women in academic professions (15th), the small fraction of high-skilled migrants (14th) and the small stock of young academics (15th).

Switzerland ranks first in four sub-indicators: education, networking, implementation and demand. In addition, it is part of the leading country group in R&D. Switzerland has relative weaknesses only in financing (11th place) - a surprising result considering the Swiss banking location - and "competition and regulation" (8th place). The low rank in innovation financing is due to a remote investment of venture capital and relatively low governmental support for R&D. Moreover Switzerland, like Germany and Sweden, gives no R&D tax credit. The major weakness of Switzerland is the Societal Innovation Climate. In comparison to other leaders, Switzerland only reaches 8th place. In particular, aspects of innovation culture, like risk aversion and participation of women (13th), need to be improved in order to become the overall leader. Another vulnerability of the Swiss innovation system is the scepticism about the control of science by scientists (17th), the distrust of science and technology (14th) and their reservation against technological benefits. But even though, they have strong negative attitudes towards science and technology, Switzerland has one of the most competitive innovation systems.

The USA shows no real weaknesses in its national innovation system. The country also faired relatively well in the overall ranking for R&D (5th place), which rated as its poorest sub-indicator. However, it is the leader due to its "innovation culture" and its general "attitudes towards science and technology". Compared to Germany and Switzerland, the United States shows a balanced innovation profile with above-average rankings in all sub-indicators. The conclusion to be drawn for Germany and other countries in the middle group is that to become a member of the leading innovation group, one must make substantial improvements to reach top scores in all seven components of the innovation system.

7 Sensitivity Analysis

Strengths and weaknesses of the weighting scheme

Although strengths should not be overemphasized, one important reason for using the PCA method is that it is able to summarize the set of individual indicators in an optimal way while preserving the maximum proportion of the total variation in original data (OECD, 2008). The other reason is that it is optimal for cross-country comparisons – especially, if countries are very similar to each other – because the weights are assigned to the indicators that have the highest variation. While single variables are very similar across countries and cannot explain the differences in performance, composite indicators on the basis of PCA have the desirable property of extracting the largest variation of single indicators and identifying country-specific differences.

The shortcomings of the PCA are merely general problems of statistically derived relations. The OECD (2008) identifies the weaknesses as:

(1) Correlations do not necessarily represent the real influence of the individual indicators on the phenomenon being measured
(2) Sensitiveness to modifications of data, presence of outliers, small-sample problems
(3) Minimization of contribution of individual indicators which do not move with other individual indicators

Although these could not be eliminated completely, our innovation indicator tries to reduce these problems. The first weakness is addressed by using components that are attributed with theoretically derived single indicators which are combined with a weighting mixture that uses the pure statistical values on lower stages and a "real world" fraction of expertise on the last stage. To reduce the sensitiveness to modifications, single variables that have a high variance over time (i.e. start-up data) are adjusted by using moving averages. The presence of outliers and small-sample problems does not occur with the innovation indicator methodology because the country set contains 17 very similar industrial countries. The third problem arises if a single indicator is negatively correlated, meaning that a logical/theoretically obvious positive relation between single variables of a component could not be found in the data. In that case we use the variance weight and neglect the covariance.

Robustness of the Results

The construction of a composite indicator depends on the underlying weighting scheme. We apply different weighting methods to measure the sensitivity of our aggregated results. The first alternative assigns every single variable the same weight. The second uses the Principal Component analysis for all aggregation steps. Finally, we use randomized weights for the sub indicators before computing the ranking of the national innovation system (Table 1).[25]

Table 1: Robustness of the national innovation system indicator 2009

Rank	**Land**	**a.) Average**	**b.) PCA**	**c.) Weighted Average**	**c.) Random Selection**	
					Median	S.D.
1	USA	1,5	1	1	1	0.47
2	CHE	6,5	5	2	3	0.88
3	SWE	1,5	2	3	2	0.62
4	FIN	4	3	4	4	0.59
5	DNK	3	4	5	5	0.57
6	CAN	6,5	7	6	6	1.15
7	JPN	9,5	9	7	9	2.02
8	NLD	5	6	8	8	0.93
9	DEU	9,5	11	9	9	1.37
10	GBR	8	8	10	8	1.49
11	KOR	12	10	11	11	1.22
12	FRA	13	12	12	13	1.18
13	AUT	14	15	13	13	0.89
14	BEL	11	13	14	14	1.16
15	IRL	15	14	15	15	1.22
16	ESP	16,5	16	16	16	0
17	ITA	16,5	17	17	17	0

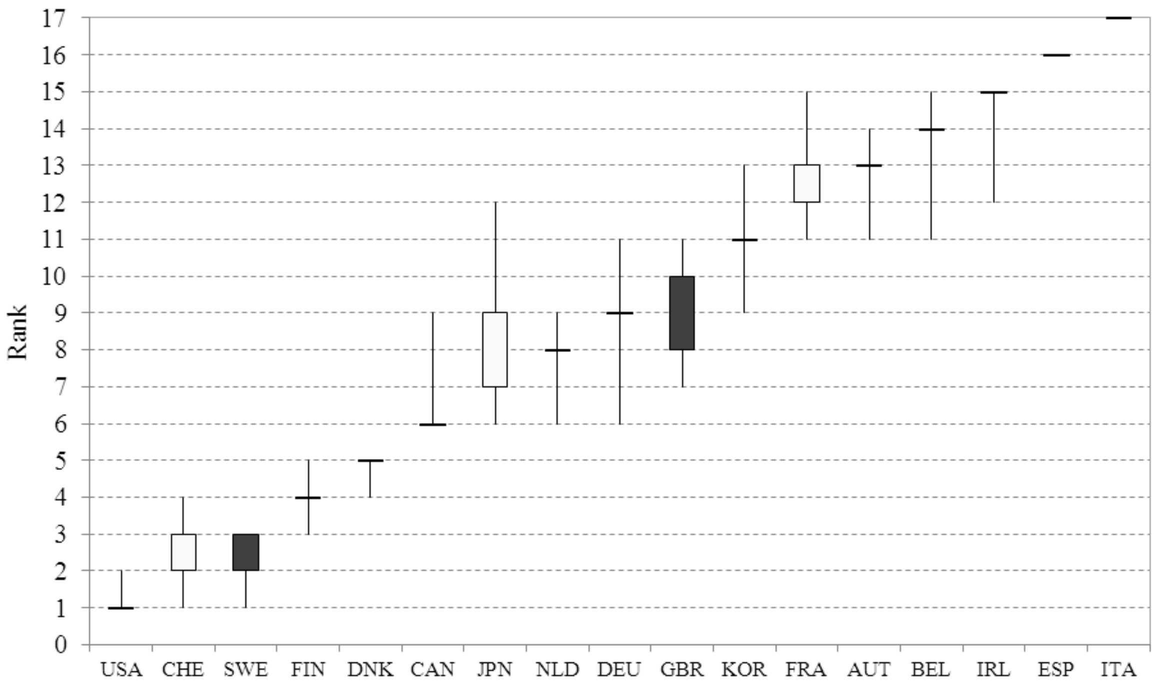
Source: own calculation

With respect to single country rankings, the different methodologies have higher variation in cases of Japan, Switzerland and Ireland. Again, we find robust evidence for the significance of three country groups by comparing ranks and standard deviations of the Random Selection Method. We measure the sensitivity of the weighting scheme by random draws (n=1000) of weights for the sub components. Thus, we can analyse mean value, median, standard deviation and the percentiles of the

[25] We refrain from analysing sensitivity for alternative normalisation, standardization, exclusion/inclusion methods as suggested by Saisana et al. (2004) because of the theoretically derived structure of the aggregated indicator.

country rankings. Figure 9 shows the difference between actual and median ranking as well as the 5% and 95% percentile. The actual rank and median value do not often fall together in the first half of the ranking. There is only a small variation in ranks for the laggard countries. Again, the three clusters can be separated very clearly, since percentiles of within followers and within leaders do not fall together. The countries with the highest variance and span width are the middle group countries, while leaders and laggards have a low variance.[26] This can be explained by the differentiated innovation profile of followers. While leaders and laggards have their strengths respectively weaknesses in almost every sub categories, followers are only innovative in one or two selective indicators. Thus, high weights in stronger categories lead to better ranks, but high weights in weak categories widen the span of possible rankings downwards.

Figure 9: NIS - Sensitivity analysis



5%, 95%, percentiles, white=actual rank < median rank, black=median rank > actual rank.

Source: own calculation

Next we compare the different results for sub indicator rankings. We find that the variation between country clusters in sub indicators do not differ significantly from aggregates indicator results (Table A.1-A.9). While innovation system leaders head the sub indicator rankings with only few exceptions, laggards compose the end section in every sub category. The middle group has a high within variation between different weighting methods. Some middle group countries have excellent results in a sub category like Germany in implementation or Netherlands in competition computed with different methods. In summary, the sensitivity analysis shows that first, for most countries, the original rank in

[26] This corresponds to the results of the UN Technology Achievement Index (OECD, 2008).

aggregated and disaggregated indicators are very close to the alternative rank. Second, leaders have their strengths in almost every sub indicator and additionally a lower variation between alternative weightings. The opposite is valid for laggards. Third, some middle group countries – i.e. Japan, Great Britain, Korea and Germany - have a high variation in aggregated ranking and thus a more differentiated innovation profile.

8 Conclusion

The innovative capacity of advanced industrial countries is the most important source of prosperity and growth for these countries. We create a robust indicator that facilitates international comparisons. The survey evaluates the ability of countries to create and transform knowledge into marketable products and services (i.e., innovations) using a system of indicators that provides an overall composite indicator of innovative capacity as well as a detailed profile of strengths and weaknesses. The structure of the composite indicator follows the recommended methodology for building composite indicators. The indicator structure facilitates analyzing innovation capacity from multiple perspectives, complete with the ability to look at aspects of the innovation system and climate. The aggregated view of national innovation systems and climate for 17 countries is, thusly, based on the performance, profile/structure, similarities and short-term dynamics for each country. The rankings can be summarized in five general findings: First, the capability of an innovation system can be measured by the overall composite indicator score. The score itself cannot be interpreted, but it allows for country rankings. Second, due to its first principal component, "performance", industrial countries can be separated into leaders, followers and laggards. The leaders are the USA, Switzerland and the Scandinavian countries. The followers are Asian countries, Central Europe and Ireland. The laggards are the Southern Europe countries. Third, considering societal innovation climate and the innovation system provides a cultural and geopolitical component that could explain weaknesses in "traditional" components of the system. The innovation climate correlates positively with traditional factors of the innovation system and provides further insight into national innovation systems. Fourth, the second principal component classifies countries with respect to their innovation structure. The innovation structure measures the strength and weaknesses of an innovation system. Here, language, cultural and geographical proximities are rather important. Thus, countries can have a similar innovation profile independent of their overall performance. Fifth, the clustered groups are stable over time but the within variation seems to be higher. Therefore, rank changes within groups should not be overvalued. Rank changes between groups highlight a significant improvement of the national innovation system.

After analysing the general results, the hierarchical structure, paired with a wide database of single indicators, allows for a detailed view on strengths and weaknesses of individual country innovation systems. Finally, of the seventeen leading industrial nations included in the survey, the US, Switzerland, Sweden, Finland, and Denmark are at the top of the list. The innovation leaders have high scores and ranks in every sub component – education, R&D, financing, networking, regulation and completion, implementation and demand. The followers or middle group has a distinctive strength and weaknesses profile. The fluctuation of scores and rankings between the sub indicators is higher than in the leading group. Thus, increasing the innovation capacity by innovation policy should be interpreted as improving all components of the system by considering the connections and interactions.

9 References

Acemoglu, D., Bimpikis, K. and Ozdaglar, A. (2008); "Experimentation, Patents, and Innovation 14408, National Bureau of Economic Research, Inc.

Aghion, P. and Howitt P. (1992); “A Model of Growth through Creative Destruction”, Econometrica, 60, pp. 323–51.

Akcomak, S. and ter Weel, B. (2009); “Social Capital, Innovation and Growth: Evidence from Europe”, European Economic Review, 53, pp. 544-67.

Ames, E. and Rosenberg, N. (1963); “Changing Technological Leadership and Industrial Growth”, Economic Journal, 74, pp. 13-31.

Arrow, K. (1972); “Gifts and Exchanges”, Philosophy and Public Affairs, 1, pp. 343-362.

Barro, R., (1998); “Determinants of Economic Growth: A Cross-Country Empirical Study?”, Cambridge, M.A.

Barro, R. J., McCleary and R. M. (2003); “Religion and Economic Growth”. NBER Working Paper 9682, Cambridge, National Bureau of Economic Research, Inc.

Baumol, W. (2004); “Education for Innovation: Entrepreneurial Breakthroughs vs. Corporate Incremental Improvements”, NBER Working Paper 10578, National Bureau of Economic Research, Inc.

Belitz, H.; Kirn, T. (2008); “Deutlicher Zusammenhang zwischen Innovationsfähigkeit und Einstellungen zu Wissenschaft und Technik im internationalen Vergleich“, DIW Vierteljahreshefte zur Wirtschaftsforschung, 77, pp. 47-64.

Butler, J. V., Giuliano, P., Guiso, L., (2009); "The Right Amount of Trust," IZA Discussion Papers 4416, Institute for the Study of Labor (IZA).

Becker, G. (1964); “Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education”, University of Chicago Press, Chicago.

Beise, M (2001); “Lead Markets – Country-Specific Success Factors of the Global Diffusion of Innovations”, ZEW Economic Studies, 14, ZEW, Mannheim.

Callon, M. (1986); “The Sociology of an Actor-Network: The Case of the Electric Vehicle”, in: Mapping the Dynamics of Science and Technology. Callon, M., Law, J. and Rip (eds), pp. 19-34 A. Macmillan Press, London.

Callon, M. (1991); “Techno-Economic Networks and Irreversibility” in: A Sociology of Monsters: Essays on Power, Technology and Domination, Law, J. (ed), pp. 132-165 Routledge, London.

Carlsson, B., (2006); "Internationalization of Innovation Systems: A Survey of the Literature", Research Policy, 35, pp. 56-67.

Clague, C. (1993); “Rule Obedience, Organizational Loyalty, and Economic Development”, Journal of Institutional and Theoretical Economics, 149, pp. 393-414.

Cohn, E. and Addison, J.T. (1988); “The Economic Returns to Lifelong Learning in OECD Countries”, Educational Economics, 6, pp. 253-307.

Conway, P. and Nicoletti, G. (2009); “Product Market Regulation in Non-Manufacturing Sectors in OECD Countries: Measurement and Highlights”, OECD Economics Department Working Paper, Paris.

Cullmann, A., Schmidt-Ehmcke, J. and Zloczysti, P. (2011); “R&D Efficiency and Barriers to Entry: A Two-Stage Semi-Parametric DEA Approach“, Oxford Economic Papers; doi: 10.1093/oep/gpr015.

Czernomoriez, J. (2009); “Internationale Wanderungen von Humankapital und wirtschaftliches Wachstum”, Volkswirtschaftliche Schriften, 557, Duncker & Humblot, Berlin.

De La Motte, L., Clemens, M. and Czernomoriez, J. (2010); „Economics of Trust: The Interbank Market During the Crisis 2007-2009”, mimeo, Potsdam.

Edquist, C. (2005); “Systems of Innovation – A Critical Review of the State of the Art”, Chapter 7, in: Handbook of Innovation, Fagerberg, J., Mowery, D. and Nelson, R. (eds), Oxford University Press.

EFI (2009); “Innovation Report 2009”, Commission of Experts for Research and Innovation, Berlin.

European Commission (2009); “European Innovation Scoreboard 2008”, Comparative Analysis of Innovation Performance, Commission Staff Working Paper, Brussels.

Florida, R. (2002a); “The Rise of the Creative Class: And How it’s Transforming Work, Leisure and Everyday Life”, Basic Books, New York.

Florida, R. (2002b); “The Economic Geography of Talent”, Annals of the American Association of Geographers, 92, pp. 743-755.

Freeman, C. (1987); “Technology Policy and Economic Performance: Lessons from Japan”, Pinter, London.

Frey, B. S. and Stutzer, A. (2002); "What Can Economists Learn from Happiness Research?", Journal of Economic Literature, vol. 40, pp. 402-435.

Frey, B. S. and Stutzer, A., (2006); "Should We Maximize National Happiness?", IEW - Working Papers, 306, Institute for Empirical Research in Economics.

Freudenberg, M. (2003); “Composite Indicators of Country Performance: A Critical Assessment”, OECD Science Technology and Industry Working Papers, 16, OECD Publishing.

Fukuyama, F. (1995); “Trust: The Social Virtues and the Creation of Prosperity”, The Free Press, New York.

Gaskell, G., Einsiedel E., Hallman W., Hornig Priest S., Jackson J. and Olsthoorn, J. (2005): “Social Values and the Governance of Science”; Science, 310, pp. 1908 – 1909.

Gee, S., Miles, I. (2008); Mini-Study 04 – Innovation Culture. PRO INNO EUROPE, INNO GRIPS, A Project for DG Enterprise and Industry.

Granato, J., Inglehart, R. and Leblang, D. (1996); “The Effects of Cultural Values on Economic Development: Theory, Hypotheses, and Some Empirical Tests”, American Journal of Political Science, 40, pp. 607-31.

Grupp, H. and Mogee, M.E. (2004); “Indicators for National Science and Technology Policy: How Robust are Composite Indicators?”, Research Policy, 33, pp. 1373-1384.

Hall, B. (2005); “Innovation and Diffusion” in: The Oxford Handbook of Innovation”, Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds), pp. 459-484, Oxford University Press, New York.

Hall, B. H. and Lerner, J. (2009); "The Financing of R&D and Innovation," NBER Working Papers 15325, National Bureau of Economic Research, Inc.

Hanushek, E.A. and Wößmann, L. (2007); „The Role of Education Quality in Economic Growth“, World Bank Policy Research Working Paper, 4122, Washington D.C.

Inglehart, R. (1997); “Modernization and Postmodernization”, Princeton University Press, Princeton, NJ.

Inglehart, R. Basanez, M., Diez-Medrano, J., Halman, L. and Luijkx, R. (2004); “Human Beliefs and Values, A Cross-Cultural Sourcebook Based on the 1999-2002 Values Surveys”, Siglo XXI Editores, Mexico.

Inglehart, R. and Welzel, C. (2005); “Modernization, Cultural Change and Democracy”; in: The Human Development Sequence, New York, Cambridge University Press.

Jacobs, J. (1961), “The Death and Life of Great American Cities”, Random House, New York.

Luhmann, N. (2000); “Vertrauen. Ein Mechanismus der Reduktion sozialer Komplexität“, UTB, Stuttgart.

Legler,H. and Frietsch, R. (2007); “Neuabgrenzung der Wissenswirtschaft - forschungsintensive Industrien und wissensintensive Dienstleistungen”, Studien zum deutschen Innovationssystem, 22, Hannover, Karlsruhe, NIW, Fraunhofer ISI.

Lundvall, B.A. (1988); “Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation”, in: Technical Change and Economic Theory, Dosi, G., Freeman, R. and Nelson, R. (eds), London, Pinter.

Lundvall, B.A. (1992); “National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning”, London, Pinter.

Mulligan, C.B. and Sala-I-Martin, X. (2004); “Measuring Aggregate Human Capital”, Journal of Economic Growth, 5, pp.215-252.

National Science Board (2008); “Science and Engineering Indicators 2008”, National Science Foundation, Arlington, USA.

Nelson, R. R. and Winter, S. (1982); “An Evolutionary Theory of Economic Change”, Harvard University Press, Cambridge, MA.

Nelson, R. R. and Wright, S. (1992); “The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective”, Journal of Economic Literature, 30, pp. 1931-1964.

Nelson, R. R. (1993); “National Innovation Systems: A Comparative Analysis”, Oxford University Press, New York, NY.

OECD (2008); “Handbook on Constructing Composite Indicators – Methodology and User Guide”, OECD, Paris.

OECD (2009); “Education at the Glance 2009”, OECD, Paris.

Patel, P. and Pavitt, K. (1995); “Patterns of Technological Activity: Their Measurement and Interpretation. in: Paul Stoneman (ed.), Handbook of the Economics of Innovation and Technological Change. Blackwell Publishers, Oxford, pp. 14-51.

Porter, M. E. (1998); “Clusters and the New Economics of Competition”, Harvard Business Review, 76, pp.77-90.

Putnam, R., Leonardi, R. and Nanetti, R.Y. (1993); Making Democracy Work, Princeton University Press, Princeton, NJ.

Ripperger, T. (1998); “Ökonomik des Vertrauens: Analyse eines Organisationsprinzips“, Mohr Siebeck, Tübingen.

Romer, P. M. (1990); “Endogenous Technological Change“, Journal of Political Economy, 98, pp. 71-102.

Saisana, M., Saltellli, M. and Tarantola, S. (2004); “Uncertainty and Sensitivity Analysis Technique as Tools for the Quality Assessment of Composite Indicators”, Journal of the Royal Statistical Society, 168, pp. 307-323.

Schumpeter, J. (1934); “The Theory of Economic Development“, Harvard University Press, Cambridge Mass.

Schneider, S. (2008); “Länderclubs mit ähnlichen Innovationssystemen”, Vierteljahreshefte zur Wirtschaftsforschung, DIW Berlin, 77, pp. 65-78.

Smith, K. (2005); “Measuring Innovation” in: The Oxford Handbook of Innovation”, Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds.), pp. 148-177, Oxford University Press, New York.

Solow, R. (1956); “A Contribution to the Theory of Economic Growth”, Quarterly Journal of Economics, 70, pp. 65-94.

Solow, R. (1957); “Technical Change and the Aggregate Production Function”, Review of Economics and Statistics, 39, pp. 312-320.

Swan, T.W. (1956); “Economic Growth and Capital Accumulation”, Economic Record, 32, pp. 334-361.

Tenenbaum, H. and Leaper, C. (2003); “Parent-Child Conversations about Science: The Socialization of Gender Inequities?” Developmental Psychology, 3, pp. 34-47.

Trajtenberg, M. (1989); “The Welfare Analysis of Product Innovations, with an Application to Computed Tomography Scanners”, Journal of Political Economy, 97, pp. 444-479.

Valian, V. (1999); “Why so Slow? The Advancement of Women”, MIT Press, Cambridge Massachusetts.

Von Hirschhausen, C., Belitz, H., Clemens, M., Cullmann, A., Schmidt-Ehmke, J. and Zloczysti, P. (2009); “Innovationsindikator Deutschland 2009”, DIW Politikberatung kompakt, 51, Berlin.

Welzel, C., Inglehart, R. and Deutsch, F. (2006); “Social Capital, Voluntary Associations and Collective Action: Which Aspects of Social Capital Have the Greatest „Civic“ payoff?”, Journal of Civil Society, 1, pp. 121-146.

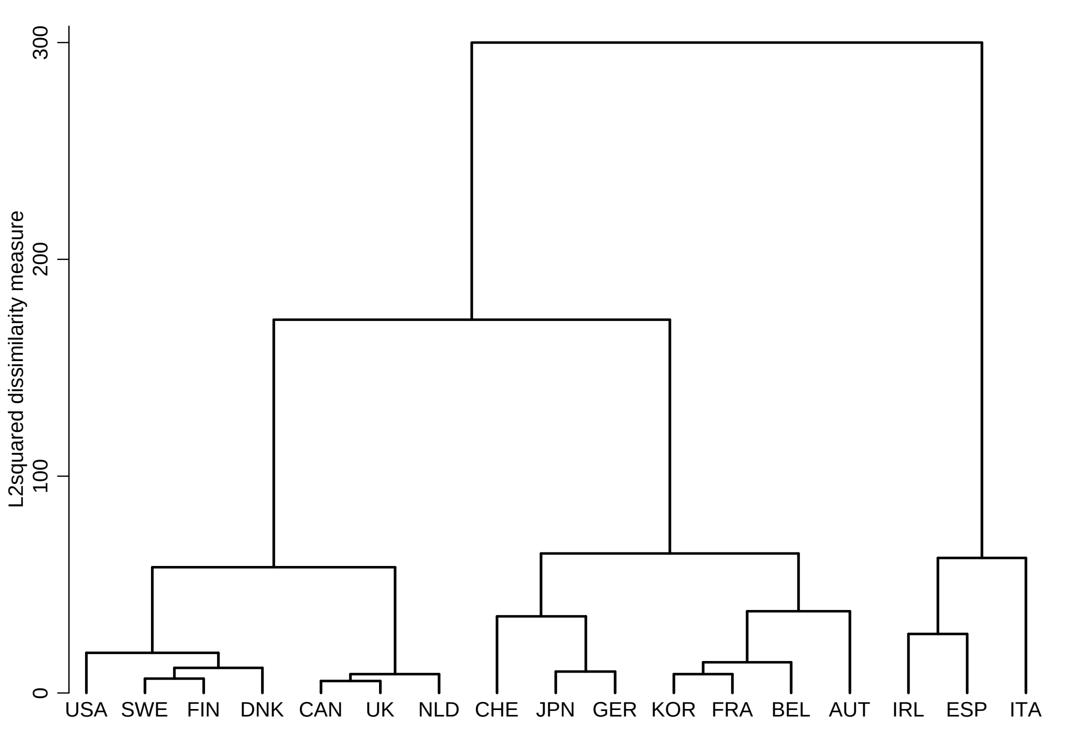
Werwatz, A., Belitz, H., Clemens, M., Schmidt-Ehmke, J., Schneider, S. and Zloczysti, P. (2008); “Innovationsindikator Deutschland 2008“, DIW Politikberatung kompakt, 45, Berlin.

World Economic Forum (2009); “The Global Competitiveness Report 2009-10”, Palgrave MacMilian, New York.

Wong, P.K., Ho, Y.P. and Autio, E. (2005); “Entrepreneurship, Innovation and Economic Growth: Evidence from GEM data”, Small Business Economics, 24, pp. 335-350.

Appendix

Figure A.1: NIS with three sub components of societal innovation climate –dendrogram (WL method)



Source: own calculation

Table A.1: NIS without the societal innovative climate - rankings

Rank	Land	a.) Average	b.) PCA	c.) Random Selection	
				Median	S.D.
1	CHE	3	1	2	0.93
2	USA	1	2	1	0.60
3	SWE	2	3	3	0.58
4	FIN	5	4	5	0.57
5	DNK	4	5	4	0.60
6	JPN	9	8	9	2.49
7	CAN	6	6	6	1.28
8	DEU	8	7	8	1.63
9	NLD	7	9	8	1.07
10	GBR	10	10	9	1.98
11	AUT	11	11	11	0.90
12	KOR	15	12	12	1.70
13	FRA	14	13	13	1.06
14	BEL	12	14	14	1.07
15	IRL	13	15	15	1.14
16	ESP	16	16	16	0
17	ITA	17	17	17	0

a) weighted average of standardized elements (actual ranking), b) average ranking of its elements, c), PCA of its standardized elements, d) random selection weights

Source: own calculation

Table A.2: Societal innovative climate

Rank	Land	a.) Average	b.) PCA	c.) Random Selection	
				Median	S.D.
1	SWE	1	1	1	0.50
2	USA	2	2	2	0.60
3	FIN	5	3	3	0.76
4	NLD	3.5	4	4	0.83
5	DNK	3.5	5	5	0.72
6	GBR	6	6	6	0.39
7	CAN	7	7	7	0.40
8	CHE	10	8	9	1.69
9	KOR	8	9	9	1.39
10	JPN	11	10	10	0.96
11	DEU	12	11	11	1.53
12	BEL	9	12	13	1.57
13	FRA	13	13	13	1.87
14	IRL	16	14	14	1.91
15	ESP	15	15	15	1.51
16	ITA	14	16	16	1.21
17	AUT	17	17	17	0.00

a) weighted average of standardized elements (actual ranking), b) average ranking of its elements, c) PCA of its standardized elements, d) random selection weights

Source: own calculation

Table A.3: Subindicator education

Rank	Land	a.) Average	b.) PCA
1	USA	5	3
2	CHE	2	1
3	SWE	4	5
4	FIN	6	6
5	DNK	1	2
6	CAN	3	4
7	JPN	9	11
8	NLD	11	10
9	DEU	15	12
10	GBR	7	7
11	KOR	12	14
12	FRA	8	8
13	AUT	13	13
14	BEL	10	9
15	IRL	14	15
16	ESP	17	16
17	ITA	16	17

a) overall ranking, b) average ranking of its elements, c) a PCA of its standardized elements

Source: own calculation

Table A.4: Subindicator R&D

Rank	Land	a.) Average	b.) PCA
1	USA	4	5
2	CHE	3	3
3	SWE	1	2
4	FIN	2	1
5	DNK	5	6
6	CAN	9	13
7	JPN	7	4
8	NLD	8	11
9	DEU	6	8
10	GBR	13,5	14
11	KOR	12	7
12	FRA	11	10
13	AUT	13,5	9
14	BEL	10	12
15	IRL	15	15
16	ESP	16,5	16
17	ITA	16,5	17

a) overall ranking, b) average ranking of its elements, c) a PCA of its standardized elements

Source: own calculation

Table A.5: Subindicator financing

Rank	Land	a.) Average	b.) PCA
1	USA	1	2
2	CHE	11	11
3	SWE	2,5	1
4	FIN	5	4
5	DNK	2,5	3
6	CAN	4	6
7	JPN	16	16
8	NLD	9	9
9	DEU	15	15
10	GBR	7,5	5
11	KOR	6	7
12	FRA	7,5	8
13	AUT	14	12
14	BEL	11	13
15	IRL	13	10
16	ESP	11	14
17	ITA	17	17

a) overall ranking, b) average ranking of its elements, c) a PCA of its standardized elements
Source: own calculation

Table A.6: Subindicator demand

Rank	Land	a.) Average	b.) PCA
1	USA	1	2
2	CHE	2	1
3	SWE	3	3
4	FIN	8	6
5	DNK	9,5	7
6	CAN	5	9
7	JPN	6	5
8	NLD	9,5	11
9	DEU	4	4
10	GBR	13	14
11	KOR	12	8
12	FRA	14	13
13	AUT	7	10
14	BEL	15	15
15	IRL	11	12
16	ESP	16	16
17	ITA	17	17

a) overall ranking, b) average ranking of its elements, c) a PCA of its standardized elements
Source: own calculation

Table A.7: Subindicator networking

Rank	Land	a.) Average	b.) PCA
1	USA	2	4
2	CHE	1	1
3	SWE	5	6
4	FIN	9	10
5	DNK	7	8
6	CAN	8	11
7	JPN	6	2
8	NLD	10	9
9	DEU	3	3
10	GBR	13	15
11	KOR	14	14
12	FRA	15	13
13	AUT	12	7
14	BEL	4	5
15	IRL	11	12
16	ESP	17	17
17	ITA	16	16

a) overall ranking, b) average ranking of its elements, c) a PCA of its standardized elements
Source: own calculation

Table A.8: Subindicator implementation

Rank	Land	a.) Average	b.) PCA
1	USA	5	3
2	CHE	1	1
3	SWE	2	2
4	FIN	6	6
5	DNK	3	4
6	CAN	14	14
7	JPN	8,5	10
8	NLD	7	8
9	DEU	4	5
10	GBR	11	11
11	KOR	13	7
12	FRA	12	12
13	AUT	10	9
14	BEL	15	15
15	IRL	8,5	13
16	ESP	16,5	16
17	ITA	16,5	17

a) overall ranking , b) average ranking of its elements, c) a PCA of its standardized elements
Source: own calculation

Table A.91: Subindicator competition

Rank	Land	a.) Average	b.) PCA
1	USA	1	1
2	CHE	5	8
3	SWE	7	9
4	FIN	6	6
5	DNK	3,5	4
6	CAN	9,5	5
7	JPN	11	10
8	NLD	2	3
9	DEU	12	13
10	GBR	3,5	2
11	KOR	15,5	14
12	FRA	15,5	16
13	AUT	8	12
14	BEL	14	15
15	IRL	9,5	7
16	ESP	13	11
17	ITA	17	17

a) overall ranking , b) average ranking of its elements, c) a PCA of its standardized elements

Source: own calculation

SFB 649 Discussion Paper Series 2011

For a complete list of Discussion Papers published by the SFB 649, please visit http://sfb649.wiwi.hu-berlin.de.

001 "Localising temperature risk" by Wolfgang Karl Härdle, Brenda López Cabrera, Ostap Okhrin and Weining Wang, January 2011.
002 "A Confidence Corridor for Sparse Longitudinal Data Curves" by Shuzhuan Zheng, Lijian Yang and Wolfgang Karl Härdle, January 2011.
003 "Mean Volatility Regressions" by Lu Lin, Feng Li, Lixing Zhu and Wolfgang Karl Härdle, January 2011.
004 "A Confidence Corridor for Expectile Functions" by Esra Akdeniz Duran, Mengmeng Guo and Wolfgang Karl Härdle, January 2011.
005 "Local Quantile Regression" by Wolfgang Karl Härdle, Vladimir Spokoiny and Weining Wang, January 2011.
006 "Sticky Information and Determinacy" by Alexander Meyer-Gohde, January 2011.
007 "Mean-Variance Cointegration and the Expectations Hypothesis" by Till Strohsal and Enzo Weber, February 2011.
008 "Monetary Policy, Trend Inflation and Inflation Persistence" by Fang Yao, February 2011.
009 "Exclusion in the All-Pay Auction: An Experimental Investigation" by Dietmar Fehr and Julia Schmid, February 2011.
010 "Unwillingness to Pay for Privacy: A Field Experiment" by Alastair R. Beresford, Dorothea Kübler and Sören Preibusch, February 2011.
011 "Human Capital Formation on Skill-Specific Labor Markets" by Runli Xie, February 2011.
012 "A strategic mediator who is biased into the same direction as the expert can improve information transmission" by Lydia Mechtenberg and Johannes Münster, March 2011.
013 "Spatial Risk Premium on Weather Derivatives and Hedging Weather Exposure in Electricity" by Wolfgang Karl Härdle and Maria Osipenko, March 2011.
014 "Difference based Ridge and Liu type Estimators in Semiparametric Regression Models" by Esra Akdeniz Duran, Wolfgang Karl Härdle and Maria Osipenko, March 2011.
015 "Short-Term Herding of Institutional Traders: New Evidence from the German Stock Market" by Stephanie Kremer and Dieter Nautz, March 2011.
016 "Oracally Efficient Two-Step Estimation of Generalized Additive Model" by Rong Liu, Lijian Yang and Wolfgang Karl Härdle, March 2011.
017 "The Law of Attraction: Bilateral Search and Horizontal Heterogeneity" by Dirk Hofmann and Salmai Qari, March 2011.
018 "Can crop yield risk be globally diversified?" by Xiaoliang Liu, Wei Xu and Martin Odening, March 2011.
019 "What Drives the Relationship Between Inflation and Price Dispersion? Market Power vs. Price Rigidity" by Sascha Becker, March 2011.
020 "How Computational Statistics Became the Backbone of Modern Data Science" by James E. Gentle, Wolfgang Härdle and Yuichi Mori, May 2011.
021 "Customer Reactions in Out-of-Stock Situations – Do promotion-induced phantom positions alleviate the similarity substitution hypothesis?" by Jana Luisa Diels and Nicole Wiebach, May 2011.

SFB 649, Ziegelstraße 13a, D-10117 Berlin
http://sfb649.wiwi.hu-berlin.de

This research was supported by the Deutsche Forschungsgemeinschaft through the SFB 649 "Economic Risk".

SFB 649 Discussion Paper Series 2011

For a complete list of Discussion Papers published by the SFB 649, please visit http://sfb649.wiwi.hu-berlin.de.

022 "Extreme value models in a conditional duration intensity framework" by Rodrigo Herrera and Bernhard Schipp, May 2011.
023 "Forecasting Corporate Distress in the Asian and Pacific Region" by Russ Moro, Wolfgang Härdle, Saeideh Aliakbari and Linda Hoffmann, May 2011.
024 "Identifying the Effect of Temporal Work Flexibility on Parental Time with Children" by Juliane Scheffel, May 2011.
025 "How do Unusual Working Schedules Affect Social Life?" by Juliane Scheffel, May 2011.
026 "Compensation of Unusual Working Schedules" by Juliane Scheffel, May 2011.
027 "Estimation of the characteristics of a Lévy process observed at arbitrary frequency" by Johanna Kappus and Markus Reiß, May 2011.
028 "Asymptotic equivalence and sufficiency for volatility estimation under microstructure noise" by Markus Reiß, May 2011.
029 "Pointwise adaptive estimation for quantile regression" by Markus Reiß, Yves Rozenholc and Charles A. Cuenod, May 2011.
030 "Developing web-based tools for the teaching of statistics: Our Wikis and the German Wikipedia" by Sigbert Klinke, May 2011.
031 "What Explains the German Labor Market Miracle in the Great Recession?" by Michael C. Burda and Jennifer Hunt, June 2011.
032 "The information content of central bank interest rate projections: Evidence from New Zealand" by Gunda-Alexandra Detmers and Dieter Nautz, June 2011.
033 "Asymptotics of Asynchronicity" by Markus Bibinger, June 2011.
034 "An estimator for the quadratic covariation of asynchronously observed Itô processes with noise: Asymptotic distribution theory" by Markus Bibinger, June 2011.
035 "The economics of TARGET2 balances" by Ulrich Bindseil and Philipp Johann König, June 2011.
036 "An Indicator for National Systems of Innovation - Methodology and Application to 17 Industrialized Countries" by Heike Belitz, Marius Clemens, Christian von Hirschhausen, Jens Schmidt-Ehmcke, Axel Werwatz and Petra Zloczysti, June 2011.

SFB 649, Ziegelstraße 13a, D-10117 Berlin
http://sfb649.wiwi.hu-berlin.de

This research was supported by the Deutsche Forschungsgemeinschaft through the SFB 649 "Economic Risk".

HUMBOLDT-UNIVERSITÄT ZU BERLIN